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UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

**PREPARATION AND KEEPING QUALITY
OF LIGHTLY SMOKED MACKEREL**

RESEARCH REPORT 6

UNITED STATES DEPARTMENT OF THE INTERIOR

Harold L. Ickes, Secretary

FISH AND WILDLIFE SERVICE

Ira N. Gabrielson, Director

Research Report 6

PREPARATION AND KEEPING QUALITY OF LIGHTLY SMOKED MACKEREL

BY

MAURICE E. STANSBY and FRANCIS P. GRIFFITHS



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ABSTRACT

SINCE at present only heavily smoked mackerel is available, the market for which is limited because of its undesirable flavor, lightly smoked mackerel similar to finnan haddie or kippered salmon should prove much more popular. Such a lightly smoked product has been prepared experimentally. It has a mild smoke flavor, which blends with but does not overshadow the natural mackerel flavor. It is very perishable, but the time during which this product can be kept in good condition can be greatly extended by freezing and holding in cold storage. Brining before smoking and freezing, using moistureproof paper wrappers, and storing at a low temperature retard development of rancidity and permit storage up to 6 months.

PREPARATION AND KEEPING QUALITY OF LIGHTLY SMOKED MACKEREL

By MAURICE E. STANSBY, *Technologist*, and FRANCIS P. GRIFFITHS, formerly *Bacteriologist, Division of Fishery Industries, Fish and Wildlife Service*

CONTENTS

	Page		Page
Introduction.....	1	Changes during preparation.....	4
Preparation.....	2	Keeping quality.....	5
Brining.....	2	Cold storage of frozen smoked product.....	6
Drying.....	2	Factors influencing rancidity.....	6
Smoking.....	3	Conclusions.....	10
Sampling procedure.....	4	Literature cited.....	10

INTRODUCTION

Fish are smoked for two reasons: to preserve them and to develop a distinctive flavor. In the early days, before modern refrigeration and canning methods were developed, salting, drying, smoking, and natural cold were the only means by which fish could be kept for any extended period. Since in smoking fish, preservation was the primary consideration, less attention was paid to developing a desirable flavor, and this tended to produce a heavily smoked product. Such heavily smoked fish were probably not considered delicacies, although a taste was eventually developed for them.

Today, most consumers do not care for a heavily smoked product, and as better methods of preservation are now available, a market for smoked fish must be developed through appealing to taste. There is a widespread demand for lightly smoked foods, as indicated by the popularity of bacon and ham. These products are no longer smoked as a means of preserving the meat but rather because of a considerable demand for them on account of their pleasing taste. The meat is smoked lightly so that the smoke flavor blends with rather than obscures the original flavor of the meat.

With the introduction of modern refrigerating methods such lightly smoked fish products as kippered salmon and finnan haddie have become popular and have a fairly widespread distribution, especially near centers of production. Finnan haddie is made from fresh fish and is retailed immediately, it being nearly as perishable as the fresh product. Kippered salmon is likewise highly perishable. The salmon, caught only in limited seasons, are usually frozen and held in cold storage until needed, when they are withdrawn, smoked, and then

eaten at once. Unfortunately, no similar product has been developed from mackerel, and since there is often a surplus of these fish, a study of the production and storage of lightly smoked mackerel was undertaken.

PREPARATION

Seven lots of about 15 mackerel each and totaling about 150 pounds were smoked. The fish were fairly uniform in size and weighed about $1\frac{1}{2}$ pounds each. All were taken in purse seines during July and August, when mackerel contain 12 to 20 percent or more of oil, and were landed 12 to 36 hours after being caught. The largest surplus of mackerel is likely to accumulate during this period, and the prices will consequently be low. The fewer fish caught in either the spring or the fall, although more desirable for smoking because the lower oil content makes them less susceptible to rancidity, are likely to be too expensive for smoking owing to the seasonal demand for fresh fish.

These samples of fish were dressed in two ways. In most cases the heads were removed, the fish split down the backbone, and the viscera removed. In a few instances the fish were filleted. The loss due to the dressing operation was about 40 percent in the first procedure and about 60 percent when fillets were cut. In commercial practice some variation from these values may be expected because dressing losses are dependent on a number of factors, including the size and fatness of the fish, and the degree of skill of the person doing the dressing.

BRINING

The dressed fish were placed in tubs of water for half an hour to remove coagulated blood, which otherwise would leave unsightly blemishes in the final product. They were then brined for 15 minutes in a 10-percent (38.5° salometer) salt solution, used in the proportion of 2 pounds of brine to 1 pound of dressed fish.

Griffiths and Lemon (1934)¹ recommended a 10-percent salt solution and a 30-minute brining period for the preparation of finnan haddie from haddock. Mackerel, however, are smaller fish of more delicate texture, and a shorter brining period proved more satisfactory. Also, it was found desirable to keep the salt concentration at the minimum, because salt accelerates the development of rancidity in fatty fish.

DRYING

In most instances the brine was drained off and the fish were hung overnight in the smokehouse in a current of air created by means of a blower. This treatment produced a glossy surface, or pellicle, which took an even smoke and made a desirable uniform-appearing product.

When the smoking process is to be completed in one day, forced drying may be used. In one experiment, the smokehouse was heated

¹ Publications referred to parenthetically by date are listed in Literature Cited, p. 10.

to 100° F., and a current of air drawn through the house by means of a blower. Drying was completed in about 4 hours, and the finished product resembled in all respects that obtained by drying overnight.

SMOKING

The experimental smokehouse described by Lemon (1932), in which temperature, humidity, and smoke density could be controlled, was used in the investigation. The fish were smoked at a temperature of 100° F. and at as low a relative humidity as possible. Air-dried oak sawdust was used to produce a smoke of moderate density. The low humidity did not cause excessive drying as would be the case with some species of fish, because the initial moisture content of the mackerel, a fat fish, was relatively low, and the water present was not readily driven off.

Fish cold-smoked 1½ hours had a very mild smoke flavor; those cold-smoked 3 to 4 hours had a mild smoke flavor; and those cold-smoked 8 hours had a moderate smoke flavor. One lot was cold-smoked 3½ hours at 100° F. and then an additional hour at 200° F. This yielded a hot-smoked product dark in color and having a strong smoky taste more nearly like that of smoked mackerel procurable in the market. The results of these fish-smoking experiments are shown in table 1.

TABLE 1.—*Results of smoking mackerel for various periods*

Product	Smoking period	Appearance	Smoke flavor
Very light-smoked.....	Cold-smoked 1½ hours at 100° F.....	Light brown.....	Very mild.
Light-smoked.....	Cold-smoked 3½ hours at 100° F.....	Medium brown.....	Mild.
Medium-smoked.....	Cold-smoked 8 hours at 100° F.....	Dark brown.....	Moderate.
Hot-smoked.....	Cold-smoked 3½ hours at 100° F., then 1 hour at 200° F.	Dark brown to black; tarry.	Strong.

The product obtained by cold-smoking 3 to 4 hours was judged to be the best and was quite different from the smoked mackerel ordinarily offered for sale. The short smoking period imparted a mild smoke taste to the flesh, yet the natural mackerel flavor was not overshadowed by that of the wood smoke, as is often the case with the more heavily smoked product. All who tasted these fish, many of whom did not care for the usual heavily smoked mackerel, declared that they were excellent in quality and had a delicate and pleasing flavor.

Fish smoked 8 hours also had a satisfactory flavor, which was preferred by a few. The wood smoke taste was more pronounced and was intermediate between that of the fish smoked 3 to 4 hours and that of regular commercial smoked mackerel.

SAMPLING PROCEDURE

There is considerable variation, particularly in the oil and water contents, of individual mackerel in the same lot. This complicates a study of the changes occurring during the preparation and storage of smoked mackerel, inasmuch as the difference that may exist initially between the individual fish may be greater than that caused by the method of preparation or by storage conditions. Hence the difference in flavor of two samples of mackerel, one of high and the other of low oil content, may be so great as to prevent an accurate appraisal of the difference caused by a light and a medium smoking process. In order to eliminate so far as possible such sources of error, all comparative analyses and tests were made on different parts of the same fish. Mackerel were cut into pieces, which were then subjected to different smoking processes and held for subsequent analyses, or the pieces smoked by one particular method were stored in various ways to test keeping quality or rancidity development.

CHANGES DURING PREPARATION

The fish samples were analyzed to determine changes in moisture content due to brining, drying, and smoking. The hot-smoked fish lost the most moisture, and the very lightly smoked ones the least. The brining process produced little change in the moisture content, and the drying operation caused a loss in weight of only about 6 percent. Table 2 shows the percentage of loss in weight of the fish at the different stages of the smoking process. In the last column is given the estimated yield from 100 pounds of dressed fresh fish smoked by various methods.

Bacterial counts were made after each step of the process, using the method described by Griffiths and Stansby (1934). Brining and drying showed no consistent effect on the bacteria. Cold-smoking substantially reduced the bacterial count, but the product was still far from sterile, with counts of 36,000 to 260,000. The hot smoke, however, almost completely sterilized the product.

TABLE 2.—Loss in weight of fish at different stages of the smoking process, and the estimated yield from 100 pounds of dressed fresh fish smoked by various methods

Smoking process	Loss in weight at each stage			Estimated yield from 100 pounds
	Sample 1	Sample 2	Average	
	Percent	Percent	Percent	Pounds
Brining.....	0.4	0.3	0.1	100.1
Drying.....	5.8	6.4	6.1	94.0
Very light-smoking.....	1.2	1.8	1.3	94.3
Light-smoking.....	17.0	16.0	16.5	78.5
Medium-smoking.....	20.2	20.0	20.1	75.1
Hot-smoking.....	27.7	27.5	27.6	68.1

¹ Increase in weight.

Tests were also made to determine the increase or decrease in the peroxide number and the free fatty-acid content of the oil in smoked mackerel by the method described by Stansby (1935). No change in peroxide number was noted during the smoking process, the value remaining zero throughout, and no rancidity could be detected by tasting the final smoked product. The free fatty-acid values were probably meaningless as such, since they included not only acid from the oil of the fish but also acetic and other acids absorbed by the fish from the wood smoke. The acidity increased proportionately with the duration of the smoking process, a maximum value of 0.035 per cent calculated as acetic acid in the flesh being attained after 8 hours of smoking.

KEEPING QUALITY

Tests to determine the keeping quality of mackerel cold-smoked for 3½ hours were conducted by storing samples in an incubator at 37° C. (99° F.), in a room at 25° C. (77° F.), and in an ice chest at 9° C. (48° F.). Unsmoked control fillets were stored under similar conditions. At the end of 2 days the smoked samples stored at 37° C. were in good condition, whereas the unsmoked controls were very stale. When stored at 25° C., the smoked fish kept in good marketable condition for 3 days, but the unsmoked for only 1 day; and when stored at 9° C., the smoked product was only slightly rancid at the end of 5 days, while the unsmoked fillets were slightly stale in 3 days. Table 3 shows the keeping quality of cold-smoked and unsmoked mackerel.

TABLE 3.—*Keeping quality of mackerel cold-smoked 3½ hours compared with that of unsmoked mackerel*

Storage period in days	Condition of fish stored at various temperatures					
	37° C. (99° F.)		25° C. (77° F.)		9° C. (48° F.)	
	Smoked	Unsmoked	Smoked	Unsmoked	Smoked	Unsmoked
2	Good.....	Very stale....	Excellent.....	Stale.....	Excellent.....	Good.
3	Very stale....	Putrid.....	Good.....	Very stale....	Good.....	Slightly stale.
4	Putrid.....	do.....	Stale.....	Putrid.....	Slightly rancid..	Rancid.
5	do.....	do.....	Very stale....	do.....	do.....	Stale; rancid.
9	do.....	do.....	Putrid.....	do.....	Stale; rancid..	Putrid.

Light and medium cold-smoked mackerel and the hot-smoked product were stored for 8 days at 25° C. After this period the light-smoked fish were putrid and rancid, the medium-smoked fish were stale and rancid, but the hot-smoked fish were still satisfactory though slightly rancid. Both of the cold-smoked fish samples had bacterial counts of 100,000,000 per gram of flesh while the hot-smoked sample showed a count of 500,000 mold organisms. These experiments demonstrate that cold-smoked mackerel are practically as perishable as

fresh untreated fish. The better keeping quality of the hot-smoked mackerel can be attributed to greater reduction in moisture content and bacterial count during the smoking operation.

COLD STORAGE OF FROZEN SMOKED PRODUCT

Since lightly smoked mackerel is so perishable a product, experiments were undertaken to determine the feasibility of freezing and cold storage. Smoked split mackerel were cut into two pieces without removing the bone, and the pieces were wrapped in moisture-proof paper and frozen by placing them in a mechanical refrigerator at 0° F. After freezing, some were placed in commercial cold-storage rooms and the rest were left in the mechanical refrigerator. At intervals pieces were withdrawn and thawed, the appearance was noted, and the fish were cooked and tasted by a number of persons. Bacterial counts were made before and after freezing the fish and after they had been kept in storage for suitable intervals.

Freezing, as would be expected, caused a substantial reduction in the bacterial count, for example, from 29,000 to 4,500; from 100,000 to 4,000; and from 15,000 to 8,000; but none of the pieces was sterile. Counts were almost invariably reduced to less than 10,000 per gram of flesh. Upon subsequent storage at 0° F., the bacterial count slowly diminished irregularly, until after 6 months of storage values were from 1,000 to 100 per gram.

The thawed product in appearance resembled the unfrozen pieces in all respects except that the gloss was less pronounced. No appreciable amount of drip formed, nor did the thawed pieces have the coarse, porous look sometimes observed in frozen fish.

Upon prolonged storage of the frozen smoked mackerel, the most important change noted was a fairly rapid development of rancidity, and this was the determining factor in limiting the period of storage. Accordingly, several series of smoked mackerel were frozen and stored under different conditions to determine the best methods of minimizing rancidity.

FACTORS INFLUENCING RANCIDITY

Freshly smoked mackerel fillets of the various series were wrapped in moistureproof paper, frozen in air at 0° F., and then stored at that temperature. After 3 months of storage, the lightest smoked fillets were already rancid, but the others showed only a slight degree of rancidity. (Table 4.) After 6 months of storage all fillets exhibited definite rancidity, although this was somewhat masked by the wood-smoke flavor. The degree of rancidity in such cases was revealed through the prolonged aftertaste.

Mackerel fillets cold-smoked 3½ hours were wrapped in moisture-proof papers, frozen in air at 0° F., and then stored at 26°, 15°, and

—5° F. After 6, 15, and 28 weeks in cold storage, some of the pieces were withdrawn, thawed, cooked, and tasted. Table 5 shows the results of these tests.

TABLE 4.—*Keeping quality of frozen smoked mackerel stored at 0° F. for 3 and 6 months*

Smoking treatment	Condition of fish after—	
	3 months	6 months
Very light cold-smoked.....	Rancid.....	Very rancid.
Light cold-smoked.....	Good; definite aftertaste.....	Rancid.
Medium cold-smoked.....	do.....	(1).
Hot-smoked.....	do.....	(1).

¹ These fish had such a strong smoke flavor as to render rancidity tests unreliable. The strong aftertaste indicated that they were at least somewhat rancid.

The samples stored at 26° F. were rancid within 6 weeks, and upon further storage the bacterial count rose and putrefaction set in. This temperature is altogether too high for successful preservation of smoked mackerel. Pieces stored at 15° F. evidenced no putrefaction even after more than 6 months of storage, but rancidity developed slowly, the fish being definitely rancid, though not inedible, after 15 weeks. The fish stored at —5° F. were still in good condition, showing no signs of rancidity, at the end of 6 weeks of storage, and even after 6 months were only slightly rancid.

TABLE 5.—*Effect of storage at 26°, 15°, and —5° F. on the keeping quality and peroxide number of frozen mackerel that had been cold-smoked 3½ hours*

Storage time in weeks	Condition of fish stored at—					
	26° F.		15° F.		—5° F.	
	Peroxide number	Condition	Peroxide number	Condition	Peroxide number	Condition
6	20	Rancid.....	12	Slightly rancid.....	0	Fresh.
15	22	do.....	22	Rancid.....	10	Slightly rancid.
28	26	Stale; rancid.....	24	do.....	11	Do.

It is evident that frozen smoked mackerel must be stored at a low temperature, preferably at 0° F. or less if rancidity is to be minimized, and even at that low temperature rancidity slowly develops.

Frozen fish stored other than in the round are usually wrapped in some kind of moistureproof wrapping material. This serves to prevent the evaporation of moisture and the consequent drying of the product, which results in loss in weight and detracts from the value by altering texture and appearance. In storing such oily fish as mackerel the wrapper also minimizes rancidity by decreasing exposure to air.

Series of samples of smoked mackerel were wrapped or covered in various ways, weighed, and frozen. After 2 months of storage at

0° F., the loss in weight and the degree of rancidity were noted. The data in table 6 indicate that the protective materials can conveniently be separated into three groups according to their efficiency.

The first and most efficient group of protective materials included transparent moistureproof paper wrappers used either alone or in combination with a waxed cardboard carton or a wooden box, and a waxed carton only. The fish in this lot after 2 months of storage showed a loss in weight of less than 1 percent and were imperceptibly or only very slightly rancid. The materials in the second group were an unwaxed carton, waxed paper wrappers and wooden box, and mineral oil glazes. These samples lost between 1 and 2 percent of their original weight in 2 months and were very slightly to definitely rancid. In the third lot either no protective device was used or a heavy mineral oil was applied, which proved only slightly better than no treatment at all. The mackerel in this group lost between 2 and 4 percent of their original weight in 2 months and were then definitely rancid.

These results indicate that desiccation is not a serious problem with frozen smoked mackerel except when the fish are stored for a long period. It is recommended, however, that a good wrapping material be used in order to decrease losses through rancidity. For this purpose a good grade of moistureproof paper is probably the best. If such a paper is used, care must be taken that the fish are carefully wrapped and sealed. Waxed cardboard cartons prove very satisfactory for packing the mackerel.

TABLE 6.—*Effectiveness of various protective materials in retarding rancidity and desiccation in frozen smoked mackerel stored at 0° F. for 2 months*

Protective material,	Rancidity	Desiccation	Loss in weight
		Percent	Percent
Transparent moistureproof paper wrappers and waxed carton.	None to very slight.....	0 to 1.....	0
Transparent moistureproof paper wrappers and unwaxed carton.			0
Waxed carton.....			0.3
Transparent moistureproof paper wrappers and wooden box.			.5
Do.....	Very slight to definite.....	1 to 2.....	.6
Unwaxed carton.....			1.2
Waxed paper wrappers and wooden box.....			1.5
Light mineral oil glaze.....			1.1
Medium mineral oil glaze.....	Definite.....	2 to 4.....	2.0
Heavy mineral oil glaze.....			2.6
No treatment.....			3.5

The degree of rancidity noted in the smoked product was greater than that which ordinarily develops in frozen mackerel, since these fish frozen in the round and kept well glazed are only slightly rancid after 3 to 6 months of storage. This increase is surprising because smoke is considered an antioxidant capable of retarding rancidity in

most products. A preliminary experiment was conducted to determine the antioxidant effect of wood smoke on mackerel oil. The oil was prepared by stirring ground mackerel flesh with ether and anhydrous sodium sulfate, filtering the ether solution through cotton, and carefully evaporating the ether. The oil so obtained was divided into two parts, and one part was treated by bubbling through it wood smoke made from oak sawdust. Both the treated and the untreated oil were then stored at -25°C. , 10°C. , and 35°C. The results, as shown in table 7, indicate that wood smoke does possess antioxidant properties, as in each case the treated oil, after 43 weeks of storage, showed lower peroxide numbers and had less rancid flavor than the untreated oil. Takahashi and Mosuda (1938) reported similar results for herring oil.

TABLE 7.—*The antioxidant effect of wood smoke on mackerel oil*

Storage period	Peroxide values at different storage temperatures					
	$-25^{\circ}\text{C. } (-13^{\circ}\text{F.})$		$10^{\circ}\text{C. } (50^{\circ}\text{F.})$		$35^{\circ}\text{C. } (99^{\circ}\text{F.})$	
	Smoked	Unsmoked	Smoked	Unsmoked	Smoked	Unsmoked
Before storing.....	1.0	1.2	1.0	1.2	1.0	1.2
43 weeks.....	1.3	9.9	5.4	45.6	24.9	34.0

Salt is known to have an accelerating influence on rancidity. Recently Banks (1938) showed that salt hastens the development of rancidity in frozen herring. A few experiments were conducted to determine whether the preliminary brining before smoking could be responsible for the increased rate of rancidity development in smoked mackerel. Pairs of mackerel fillets, in which one of each pair received no treatment and the other was dipped in a 10-percent salt solution exactly as were the smoked mackerel, were wrapped in moistureproof paper and stored at 0°F. The salted fillets became rancid within 2 months, while the untreated ones were only slightly rancid after 6 months.

These results indicate that the preliminary brining treatment should be as short as possible in order that the development of rancidity in the smoked product kept in storage may be retarded. If the mackerel are to be stored for more than 6 months, it may be necessary to omit the brining process, although this will alter the flavor and the fillets will not have the normal glossy surface.

The more rapid development of rancidity in frozen smoked mackerel than in frozen mackerel suggests the possible advantage of holding surplus mackerel frozen and preparing the smoked product from the frozen fish. In preliminary tests, however, frozen mackerel failed to develop the smooth, glossy surface considered desirable in smoked fish. Unfortunately, it became necessary at that time to discontinue further

studies on smoked mackerel because the laboratory was moved from Gloucester, Mass., to College Park, Md.

CONCLUSIONS

The present market for smoked mackerel is limited as only a heavily smoked product is available, which is not popular with most consumers because of undesirable flavor. A lightly smoked product similar to finnan haddie or kippered salmon should find a much wider market.

A satisfactory lightly smoked mackerel has been prepared experimentally. It has a mild smoke flavor, which blends with but does not overshadow the delicate, normal mackerel flavor.

Lightly smoked mackerel is nearly as perishable as the fresh, unsmoked fish and must be handled accordingly.

The period during which smoked mackerel may be kept in good condition can be greatly increased by freezing the product and holding it in cold storage.

The storage time of frozen smoked mackerel can be increased by shortening the preliminary brining period before smoking, by using a moistureproof wrapper after smoking, and by storing at as low a temperature as possible, preferably below 0° F. These precautions retard the development of rancidity and permit storage for periods up to 6 months.

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